

Corey J. Keller, MD PhD
Medical Resident & Postdoctoral Researcher
ckeller1@stanford.edu

Education

Residency, Psychiatry	Stanford University, Palo Alto, CA	2019
Postdoctoral Fellowship	Stanford University, Palo Alto, CA	2019
MD	Albert Einstein College of Medicine, Bronx, NY	2015
PhD, Neuroscience	Albert Einstein College of Medicine, Bronx, NY	2015
MS, Biomedical Engineering	Harvard (research), Tufts (courses), Boston, MA	2009
BS, BME / EE	Tufts University, Medford, MA	2007

Research Interests

- 1) *Elucidate the relationship between cortical network dynamics (over a range of steady states and stimulation) with psychiatric symptoms*
- 2) *Identify and apply individualized brain stimulation protocols to elicit precise and predictable long-term plasticity to alleviate psychiatric suffering*
- 3) *Investigate the origins of spontaneous oscillations, which form the functional repertoire of brain networks*

Awards and Honors

2018	Alpha Omega Alpha Medical Honor Society	
2018	Stanford Society of Physician Scholars Collaborative Research Fellowship	
2018	NIMH T32 Postdoctoral Fellowship	
2018	Career Development Institute for Psychiatry	
2017	NIMH Outstanding Resident Award	
2017	ASCP New Investigator Award	
2017	Winter Conference on Brain Research Travel Fellowship	
2017	Society of Biological Psychiatry Early Career Investigator Travel Award	
2016	BrainBox Neuroscience Initiative Young Investigator Award	
2016	Alpha Omega Alpha Postgraduate Research Award	
2015	American Society of Clinical Psychopharmacology Fellowship for Clinical Trials	
2015	Stanford Society of Physician Scholars Collaborative Research Fellowship	
2014	Society of Biological Psychiatry Medical School Scholar	
2014	NINDS Combining Clinical and Research Careers in Neuroscience Travel Award	
2013	Albert Einstein College of Medicine Senior Research Fellowship	
2011-2015	Neural Systems and Behavior Course Endowed Scholarship Fund	Ruth
	L. Kirschstein National Research Service Award Medical Scientist Training Program	
2010-2011	Pre-Doctoral Fellowship	
2009	Epilepsy Foundation Pre-Doctoral Research Training Fellowship	
2009	Albert Einstein College of Medicine Grant for Summer Research	
2007	Master's Thesis Highest Honors	
2007	Magna Cum Laude and Senior Thesis Highest Honors	
2004-2007	Eta Kappa Nu – Electrical Engineering Honors Society	
	Dean's List Honors, Tufts University	

Postdoctoral Work

2015-	<i>Towards precise neuromodulatory control of human cortical circuits</i> Amit Etkin, MD PhD, Stanford University
2014-	<i>Spike-timing dependent plasticity in human cortex</i> Ashesh Mehta, MD PhD, Feinstein Institute for Medical Research
2014-2015	<i>Population activity in the mouse dorsal striatum</i> Kamran Khodakhah, PhD, Albert Einstein College of Medicine

Personal Statement

My career goal is to be a leader in therapeutic brain stimulation and human electrophysiology. My work is to map the interaction between brain networks, stimulation-induced brain changes, and neuropsychiatric symptoms. I plan to combine my backgrounds in electrophysiology, bioengineering, and neuroscience to perform translational research while practicing as an interventional psychiatrist, with a focus on mood disorders and treatment-resistant depression. During my PhD, I developed novel intracranial brain mapping tools and applied these to demonstrate the neural basis of resting functional MRI in humans. During residency, I co-developed fully automated non-invasive brain mapping techniques, now used across industry and academia. I have published 20+ journal articles (13 first-author), wrote two first-author book chapters, delivered 10+ invited lectures, (5+ internationally), mentored 8 students (two with first-author publications under my supervision), been awarded multiple grants including an F31 and K23 (fundable score), generated two patents, and oversee two clinical trials (NCT01829165 and NCT02843373) across nine clinical centers.

My 10 year research aims are to: 1) develop an integrated translational clinical research program; 2) identify the specific neural mechanisms underlying human brain plasticity, and 3) develop platforms for rapid biomarker development, evaluation, and integration into personalized brain stimulation treatments. This three-pronged approach has the expected outcome of producing novel stimulation treatments with enhanced specificity, plasticity, and efficacy. By increasing our mechanistic understanding and ability to monitor brain changes during stimulation, we will markedly increase the utility of these powerful techniques. Together, this work will help transform interventional psychiatry from a one-size-fits-all treatment approach to one that focuses on targeting objective biomarkers and that is collaborative, individualized, large-scale, and automated, pushing the field into the age of personalized neurotherapeutics.

Contribution to Science

1. My early work in the laboratory of Sydney Cash focused on the mechanisms underlying inter-ictal spikes, which define epileptic cortex. We recorded simultaneous local field potentials and single neuron action potentials during inter-ictal discharges (IID) using high density microelectrode arrays implanted in patients with medically-resistant epilepsy to characterize the firing pattern that underlies IIDs. We determined that only $\frac{1}{2}$ of neurons in epileptic areas modulate their firing rate during IIDs. Furthermore, as expected $\frac{1}{4}$ of neurons increased their firing rate during the IID. In direct contrast to predictive models of the IID, however, we identified a subset of population of neurons that modulate their firing rate *prior* to the IID. These subset of neurons were only observed in epileptic regions, suggesting they may play a role in the generation of the IID. During this time, we also developed a microelectrode that records simultaneous electrophysiology and hemodynamics and an algorithm for accurately localizing intracranial electrodes implanted in patients during epilepsy surgery.
 - a. **Keller CJ**, Cash SS, Narayanan S, Wang C, Kuzniecky R, Carlson C, Devinsky O, Thesen T, Doyle W, Sassaroli A, Boas AD, Ulbert I, Halgren E. *Intracranial microprobe for evaluating neuro-hemodynamic coupling in unanesthetized human neocortex*. Journal of Neuroscience Methods 179 (2009) 208–218.
 - b. Dykstra A, Chan AM, Quinn BT, Zepeda R, **Keller CJ**, Cormier JE, Madsen JR, Eskandar EN, Cash SS. *Individualized localization and cortical surface-based registration of intracranial electrodes*. NeuroImage 59 (2012): 3563–70.
 - c. **Keller CJ**, Truccolo W, Gale JT, Eskandar E, Thesen T, Carlson C, Devinsky O, Kuzniecky R, Doyle WK, Madsen JR, Schomer DL, Mehta AD, Brown EN, Hochbert LR, Ulbert I, Halgren E, Cash SS. *Distinct Neuronal Firing Types During Interictal Epileptiform Discharges in the Human Cortex*. Brain 133 (2010) 1668–81.
2. During my PhD with Ashesh Mehta, Fred Lado, and Michael Milham, with a team of interdisciplinary collaborators, we documented the relationship between fMRI and underlying physiology. fMRI is now in mainstream use, but the neurophysiology of positive and negatively correlated BOLD fluctuations – which consistently identify large scale networks implicated in cognitive, sensory, and motor functions, and which differentiate patients from healthy subjects in many neuropsychiatric diseases – is largely unknown and confounded by multiple artifacts that exist in these recordings. I directly demonstrated that the spatial distribution and magnitude of temporally correlated low-frequency BOLD fluctuations ('resting fMRI') predict the pattern and magnitude of evoked potentials measured intracranially following focal electrical stimulation. These findings were replicated across patients and functional subsystems and strengthened the notion that resting fMRI signals are grounded in neurophysiology. We furthermore demonstrated that positively and negatively correlated fluctuations of high gamma activity underlie positive and negative BOLD correlations, respectively, suggesting that both resting BOLD interactions have neurophysiological origins in slow power modulations of fast frequency activity. This work has driven >20 groups across the world to begin collecting cortico-cortical evoked potentials (CCEPs), where a causal electrical disturbance in the brain elicits brief changes in neuronal excitability that can be measured in the local field potential.
 - a. **Keller CJ**, Bickel S, Entz L, Ulbert I, Kelly C, Milham M, Mehta AD. *Intrinsic functional architecture predicts electrically-evoked responses in the human brain*. **Proceedings**

- of the National Academy of Sciences 108 (2011): 10308-13.
- b. Keller CJ, Bickel S, Honey CJ, Groppe DM, Craddock CR, Kelley C, Lado FA, Milham M, Mehta AD. *Neurophysiological investigation of spontaneous correlated and anticorrelated fluctuations of the BOLD signal*. **Journal of Neuroscience**. 33 (2013): 6333-42.
 - c. Keller CJ, Honey CJ, Entz L, Bickel S, Groppe DM, Toth E, Lado FA, Ulbert I, Mehta AD. *Probing the human connectome: cortico-cortical evoked potentials reveal projectors and integrators within human brain networks*. **Journal of Neuroscience**. 34 (2014): 9152-63.
 - d. Keller CJ, Honey CJ, Megevand P, Entz L, Ulbert I, Mehta AD. *Mapping complex brain networks with cortico-cortical evoked potentials*. **Philosophical Transactions of the Royal Society B: Biological Sciences**. 1 (2014): 369 (1653).
3. As a post-doctoral fellow with Amit Etkin, I co-developed a fully automated analytic pipeline for analysis of concurrent transcranial magnetic stimulation (TMS) coupled with EEG. This toolbox is currently being used across 10 different projects examining plasticity abnormalities in multiple patient populations. We also performed a randomized, double-blind, placebo-controlled clinical trial to investigate the electrophysiological underpinnings of clinical effects of daily repetitive TMS (rTMS) treatment for depression. We utilized the toolbox developed to show that rTMS treatment modulates TMS-evoked potentials and the strength of modulation predicts clinical outcome. This work suggests that specific TMS-EEG brain-based biomarkers may be used to predict non-responders, monitor brain networks during intervention, and be used to propose novel targets and treatment paradigms.
- a. Keller CJ*, Wu W*, Etkin A. *ARTIST: A Fully Automated Artifact Rejection Algorithm for Single-Pulse TMS-EEG Data*. In press: **Human Brain Mapping**. *These authors contributed equally.
 - b. Keller CJ*, Kerwin L*, Wu W, Etkin A. *Test-Retest Reliability of Transcranial Magnetic Stimulation EEG Evoked Potentials*. In press: **Brain Stimulation**. *These authors contributed equally.
 - c. Keller CJ*, Fischer AS*, Etkin A. *The clinical applicability of functional connectivity in depression: Pathways toward more targeted intervention*. **Journal of Biological Psychiatry: Cognitive Neuroscience and Neuroimaging**. 3 (2016): 262-270. *These authors contributed equally.
 - d. Keller CJ*, Huang D*, Honey CJ, Du V, Fini M, Lado FA, Etkin A, Mehta AD. *Induction and quantification of plasticity in human cortical networks*. In press: **Journal of Neuroscience**. *These authors contributed equally.

Thesis Work

PhD Dissertation: *Investigating the neurophysiological origins of spontaneous fluctuations of the BOLD signal, high frequency oscillations, and the default mode network.*

Dept of Neuroscience, Albert Einstein College of Medicine

07/2011 – 10-2013 ; High Honors

Mentors: Drs Fred Lado and Ashesh Mehta

Advisory Committee: Adam Kohn, Kamran Khodokakhah,
Joseph Arezzo, Charles Schroeder

Master's Thesis: *Seeking the Neuro-Hemodynamic Basis of Epilepsy: Evidence from Human Intracranial EEG, Laser Doppler Flowmetry, Cortical Point Spectroscopy, and Single Unit Activity*

Dept of Biomedical Engineering, Tufts University

09/2007 – 05-2009; Highest Honors

Mentors: Sergio Fantini (Tufts); Sydney Cash (Harvard)

Positions and Employment

- 2018-2019 NIMH T32 Postdoctoral Fellowship, Stanford University School of Medicine
- 2018- AOA, Research and Grants Chair
- 2017- Clinical TMS Society, Research Committee Member
- 2016- International Neuromodulation Society, Research and Scientific Oversight
- 2015- Psychiatry Resident, Stanford University
- 2009-2015 Postdoctoral Research Fellow, Etkin Lab, Stanford University
- 2007-2009 Research Scientist, Laboratory for Multimodal Human Brain Mapping, NS LIJ Hospital, Manhasset, NY
- 2007-2009 Research Scientist, Cortical Physiology Laboratory, Department of Neurology, Massachusetts General Hospital, Boston, MA
- 2006 Research Scientist, Multimodal Neuroimaging Lab, Martinos Center for Biomedical Engineering, Harvard Medical School, Boston, MA
- Research Scientist, Tissue Engineering Lab, Tufts University, Medford, MA

United States Medical Licensing Exams

Step 1: 240 / 99

Step 2: 242

Patents

1. Keller CJ, Etkin A, Wu W. *Use of a brain-based signal for predicting and guiding brain stimulation treatment in depression.* U.S. Patent Application 41243-520P01US, filed April 2016. Patent Pending.
2. Etkin A, Keller CJ, Wu W. *Artifact Rejection for Transcranial Magnetic Stimulation Electroencephalogram Data.* U.S. Patent Application 41243-520P02US, filed December 2016. Patent Pending.

Clinical Trials

1. NCT02843373. *Brain-Based Biomarkers in Response to TMS in MDD.* Role: Co-Investigator.
2. NCT02479906. *A Safety and Efficacy Study with Deep Transcranial Magnetic Stimulation for the Treatment of Post-Traumatic Stress Disorder (PTSD).* Role: Co-Investigator.

Research Support

Pending

NIMH K23 Mentored Research Career Development Award

Corey J Keller (PI)

Electrophysiological basis of cortical plasticity in repetitive transcranial magnetic stimulation

Source: NIMH

\$850,000 over 5 years

Status: Impact score of 17 on 5/2018

Repetitive transcranial magnetic stimulation (rTMS) is an effective treatment for depression, but clinical outcome is suboptimal because we don't understand how rTMS affects the brain. Using TMS paired with EEG, this proposal will 1) test how brain changes relate to clinical outcome and 2) establish a computational model to help predict outcome and propose novel treatment protocols.

NIH DP5 Early Independence Award

Corey J Keller (PI)

Closing the loop: development of real-time, personalized brain stimulation

Source: NIH Common Fund

\$1,250,000 over 5 years

Status: Pending review

BWF Career Award for Medical Scientists

Corey J Keller (PI)

Source: BWF

\$700,000 over 5 years

Status: Finalist

Active

T32-MH019938

Alan Schatzberg (PI)

07/2018-07-2019

Source: NIMH

Postdoctoral Research Training Fellowship in Clinical Psychiatry

Stanford Society for Physician Scholars

Corey J Keller (PI) 2018-2019

Modeling of human neuroplasticity following repetitive stimulation

A 1-year internal fellowship that pairs residents with medical students. Goals of the project include determining the relationship between baseline neuronal state, dynamics during stimulation, and plasticity following stimulation. This work will provide a framework for identifying patients refractory to rTMS therapy and lead to development of closed-loop rTMS systems that maximizes individual neuroplasticity.

Completed

AOA Postgraduate Award

Corey J Keller (PI) 2016-2017

A 1-year fellowship to develop brain monitoring techniques during TMS treatment.

Stanford Society for Physician Scholars

Corey J Keller (PI) 2015-2016

Induction and quantification of long-term plasticity in the human brain

A 1-year internal fellowship that pairs residents with medical students. Goals of the project included a multimodal approach to investigate the intracranial mechanisms underlying how repetitive stimulation induces brain plasticity and changes in cortical connectivity.

F31 NS080357 **Corey J Keller (PI)** **07/01/2011-2015**
Localizing functional and pathological networks in epilepsy
Source: **NINDS** **\$367,000 over 4 years**

Ruth L. Kirschstein National Research Service Award. This proposed study has two fundamental goals. (1) To determine the relationship between networks derived from neuroimaging and electrophysiology techniques, and 2) To localize functional and pathological networks using complementary methods from multiple recording techniques. The long term goal of this research is the application of network analysis to multimodal imaging to 1) better understand the relationship between non-invasive and invasive imaging and 2) develop more accurate techniques to localize epileptic networks to improve surgical outcome.

EFA189045 **Corey J Keller (PI)** **07/2010 – 07/2011**
Localizing networks with evoked potentials and resting state fMRI
Source: **Epilepsy Foundation** **\$21,000**

Epilepsy Foundation Pre-Doctoral Research Training Fellowship. The goal of this research was to develop novel methods for identifying functional regions to be preserved and pathological regions to be safely removed in order to control medically refractory epilepsy. This project proposed to identify functional and epileptogenic regions of brain using two methods, measurements from recordings of electrodes inside the brain and by measuring the blood flow at rest from outside the brain. This research has important significance in bridging the gap between invasive and non-invasive recordings, improving efficacy of localizing the seizure zone, and improving surgical outcome.

T32-GM007288 **Myles Akabas (PI)** **07/2011-07-2013**
Source: **NIH** **\$225,000 over 3 years**
Medical Scientist Training Program Pre-Doctoral Fellowship

Book chapters

1. Keller CJ, Bhati M, Downar J, Etkin A. *Brain Stimulation Therapies*. In: **The American Psychiatric Publishing Textbook of Psychiatry**. 6th Edition, 2018.
2. Wu, W, Keller, CJ, Etkin, A. *Artifact Rejection for Concurrent TMS-EEG Data*. In *Dynamic Neuroscience: Statistics, Modeling, and Control*. (eds. Chen, Z. & Sarma, S.V.) 141-173, Springer International Publishing, Cham, 2018.
3. Keller CJ, Philips N, Bhati M, Wu W, McTeague L, Etkin A. Neurostimulation – PTSD and Anxiety Disorders. *In preparation*.

Peer-reviewed publications

Published / Under Review

1. Huang D, Herrero J, Entz L, Fabo D, Hajnal B, Mehta A, Keller CJ. *Intracrain cortical dynamics predicts and tracks neuronal plasticity. Submitted: Nature Communications. Impact: 12.*
2. Keller CJ, Eshel N, Wu W, Jang J, Huemer J, Mills-Finnerty C, Wright R, Ichikawa N, Fonzo G, Sphigel S, Wong M, Yee A, McTeague L, Etkin A. *Neural basis of repetitive transcranial magnetic stimulation in depression. Under review: American Journal of Psychiatry. Impact: 12*
3. Belardinelli P, ... Keller CJ, ..., Ilmoniemi R. Reproducibility in TMS-EEG studies: a call for data sharing, standard procedures and effective experimental control. *Accepted: Brain Stimulation. Impact: 6.0.*
4. Entz L, Fabo D, Keller CJ, Ulbert I, Mehta AD. *Cortical electrical stimulation induces slow oscillations in the awake human state. Under review: Brain. Impact: 9.2*
5. Keller CJ, Huang D, Honey CJ, Du V, Fini M, Lado FA, Mehta AD. *Induction and quantification of excitability changes in human cortical networks. In press: Journal of Neuroscience. Impact: 7.2*
6. Keller CJ*, Wu W*, Rogasch NC, Longwell P, Spigel E, Rolle CE, Etkin A. *ARTIST: A Fully Automated Artifact Rejection Algorithm for Single-Pulse TMS-EEG Data. Human Brain Mapping.* 00 (2018): 1-19. **Impact: 5.9.** *These authors contributed equally.
7. Keller CJ*, Kerwin L*, Wu W, Etkin A. *Test-Retest Reliability of Transcranial Magnetic Stimulation EEG Evoked Potentials. In press: Brain Stimulation.* *These authors contributed equally. **Impact: 6.0.**
8. Megevand P, Groppe DM, Bickel S, Mercier M, Goldfinger MS, Keller CJ, Entz L, Mehta AD. *The hippocampus and amygdala are integrators of distributed neocortical influence: a cortico-cortical evoked potential study. Brain Connectivity.* 10 (2017): 648-660. **Impact: 4.0.**
9. Etkin A, Fonzo G, Huemer J, Patenaude B, Vertes P, Richiardi J, Goodkind M, Keller CJ, et al. *Connectomics and cognition define a distinct form of post-traumatic stress disorder. In press: Science Translational Medicine. Impact: 16.7.*
10. Keller CJ, Davidesco I, Megevand P, Groppe DM, Lado FA, Mehta AD. *Tuning face perception with electrical stimulation of the fusiform gyrus. Human Brain Mapping.* 6 (2017): 2830-2842. **Impact: 5.9.**
11. Bott N, Keller CJ, Kuppuswamy M, Spelber D, Zeier J. *Cotard Delusion in the Context of Schizophrenia: A Case Report and Review of the Literature. In press: Frontiers of psychology.*
12. Keller CJ*, Fischer AS*, Etkin A. *The clinical applicability of functional connectivity in depression: Pathways toward more targeted intervention. Journal of Biological Psychiatry: Cognitive*

- Neuroscience and Neuroimaging.** 3 (2016): 262-270. *These authors contributed equally.
13. Keller CJ, Chen EC, Brodsky K, Yoon J. *A case of butane hash oil (marijuana wax)-induced psychosis.* **Substance Abuse.** 33 (2016): 384-386. **Impact: 2.0**
 14. Keller CJ, Chen C, Lado FA, Khodokakhah K. *The limited utility of high frequency activity in differentiating neuronal population dynamics in the mouse striatum.* **PLoS One.** 11 (2016): 1-20. **Impact: 3.2**
 15. Entz L, Toth E, Keller CJ, Groppe DM, Megevand P, Fabo D, Ulbert I, Eross LG, Mehta AD. *The human neocortex demonstrates projectors and integrators of influence: a consideration in neuromodulation therapy.* **Neurosurgery.** 61 (2014): 1:224.
 16. Keller CJ, Honey CJ, Megevand P, Entz L, Ulbert I, Mehta AD. *Mapping complex brain networks with cortico-cortical evoked potentials.* **Phil Trans Royal Soc B.** 369 (2014): 1-14. **Impact: 6.2**
 17. Keller CJ, Honey CJ, Entz L, Bickel S, Groppe DM, Toth E, Lado FA, Ulbert I, Mehta AD. *Probing the human connectome: cortico-cortical evoked potentials reveal projectors and integrators within human brain networks.* **Journal of Neuroscience.** 34 (2014): 9152-63. **Impact: 7.2**
 18. Entz L, Toth E, Keller CJ, Bickel S, Groppe D, Fabo D, Kozak LR, Eross L, Ulbert I, Mehta AD. *Effective connectivity of the human neocortex derived from direct electrocortical stimulation.* **Human Brain Mapping.** 12 (2014): 5736-53. **Impact: 5.9.**
 19. Groppe DM, Bickel S, Keller CJ, Jain SK, Hwang ST, Harden C, Mehta AD. *Dominant frequencies of resting human brain activity as measured by the electrocorticogram.* **NeuroImage.** 79 (2013): 223-33. **Impact: 5.9**
 20. Davidesco I, Zion-Golumbic E, Keller CJ, Bickel S, Harel M, Groppe DM, Schroeder C, Mehta AD, Malach R. *Exemplar selectivity reflects perceptual similarities in the human fusiform cortex.* **Cerebral Cortex.** 24 (2014): 1879-93. **Impact: 6.8**
 21. Keller CJ, Bickel S, Honey CJ, Groppe DM, Craddock CR, Kelley C, Lado FA, Milham M, Mehta AD. *Neurophysiological investigation of spontaneous correlated and anticorrelated fluctuations of the BOLD signal.* **Journal of Neuroscience.** 33 (2013): 6333-42. **Impact: 7.2**
 22. Dykstra A, Chan AM, Quinn BT, Zepeda R, Keller CJ, Cormier JE, Madsen JR, Eskandar EN, Cash SS. *Individualized localization and cortical surface-based registration of intracranial electrodes.* **NeuroImage** 59 (2012): 3563-70. **Impact: 5.9**
 23. Keller CJ, Bickel S, Entz L, Ulbert I, Kelly C, Milham M, Mehta AD. *Intrinsic functional architecture predicts electrically-evoked responses in the human brain.* **Proceedings of the National Academy of Sciences** 108 (2011): 10308-13. **Impact: 10.2**
 24. Keller CJ, Truccolo W, Gale JT, Eskandar E, Thesen T, Carlson C, Devinsky O, Kuzniecky R, Doyle WK, Madsen JR, Schomer DL, Mehta AD, Brown EN, Hochbert LR, Ulbert I,

Halgren E, Cash SS. *Distinct Neuronal Firing Types During Interictal Epileptiform Discharges in the Human Cortex*. *Brain* 133: (2010) 1668-81. **Impact: 9.2**

25. Keller CJ, Cash SS, Narayanan S, Wang C, Kuzniecky R, Carlson C, Devinsky O, Thesen T, Doyle W, Sassaroli A, Boas AD, Ulbert I, Halgren E. *Intracranial microprobe for evaluating neuro-hemodynamic coupling in unanesthetized human neocortex*. *Journal of Neuroscience Methods* 179 (2009) 208–218. **Impact Factor: 2.1**
26. Gow DW, Jr, Keller CJ, Eskandar E, Meng N, Cash SS. *Superior temporal coordination of the perisylvian speech network: A Granger analysis of intracranial EEG data*. *Brain and Language*, 110 (2009) 43-8. **Impact: 2.8**

In preparation

27. TMS-EEG Biomarkers for Combat-Related Post-Traumatic Stress Disorder.
28. Keller CJ, Davidesco I, Entz L, Bickel S, Toth E, Groppe D, Ulbert I, Lado FA, Malach R, Mehta AD. *The electrophysiological signature of the default mode network*. *In preparation*.
29. Wu W*, Keller CJ*, et al. Brain-based biomarkers for left versus right-sided rTMS in depression. *In preparation*.
30. Keller CJ, Wu W, Kerwin L. Single rTMS session modulates the TMS-evoked potential. *In preparation*.

Presentations / Abstracts

1. Keller CJ, Wu W, Wright R, Rolle C, Sarhadi K, Ichikawa N, Huemer J, Wong M, Yee A, McTeague L, Fini M, Du V, Honey CJ, Lado F, Mehta AD, Etkin A. Repetitive brain stimulation induces long-term plasticity across patient populations and spatial scales. Human Brain Mapping, Geneva, Switzerland, June 2016.
2. Mehta AD, Megevand P, Du V, Yeagle E, Herrero J, Mercier M, Bickel S, Keller CJ, Groppe DM, Entz L, Davis B, Argyelan M. Correspondence of BOLD- and Electrophysiology-Based Connectivity Dynamics Before and After Corpus Callosotomy. Human Brain Mapping, Geneva, Switzerland, June 2016.
3. Keller CJ, Wu W, Wright R, Rolle C, Sarhadi K, Ichikawa N, Huemer J, Wong M, Yee A, McTeague L, Fini M, Du V, Honey CJ, Lado F, Mehta AD, Etkin A. Repetitive brain stimulation induces long-term plasticity across patient populations and spatial scales. Brain Stimulation and Imaging, Geneva, Switzerland, June 2016.
4. Du V, Keller CJ, Herrero J, Yeagle E, Khuvis S, Mehta AD. Modifying neural circuits with dual-site stimulation. Feinstein Institute for Biomedical Research Conference, Cold Spring Harbor Laboratory, New York, June 2016.
5. Keller CJ, Wu W, Wright R, Rolle C, Sarhadi K, Ichikawa N, Huemer J, Wong M, Yee A,

- McTeague L, Fini M, Du V, Honey CJ, Lado F, Mehta AD, Etkin A. Repetitive brain stimulation induces long-term plasticity across patient populations and spatial scales. Society of Biological Psychiatry, Atlanta, May, 2015
6. **Keller CJ**, Fini M, Honey CJ, Lado FA, Mehta AD. Optimizing repetitive brain stimulation using direct electrical recordings from human brain networks. Society for Neuroscience, Chicago, IL, October, 2015.
 7. **Keller CJ**, Fini M, Honey CJ, Lado FA, Mehta AD. Induction and quantification of plasticity in human cortical networks using repetitive brain stimulation. Human Brain Mapping, Honolulu, HI, June, 2015.
 8. **Keller CJ**, Fini M, Honey CJ, Lado FA, Mehta AD. Induction and quantification of plasticity in human cortical networks using repetitive brain stimulation. Society of Biological Psychiatry, Toronto, CA, May, 2015.
 9. Entz L, Megevand P, Groppe DM, Toth E, Fabo D, Fallil Z, Hwang ST, Harden CL, Bickel S, **Keller CJ**, Mehta AD. Exploring seizure networks using cortico-cortical evoked potentials: internally hyperconnected, externally hypoconnected? American Epilepsy Society, Seattle, WA, December 2014.
 10. **Keller CJ**, Davidesco I, Megevand P, Groppe DM, Lado FA, Mehta AD. A causal role of the fusiform face area in face perception. Society for Neuroscience, Washington DC, November, 2014.
 11. Groppe D, Megevand P, Bickel S, Mercier M, **Keller CJ**, Goldfinger MS, Mehta AD. Electrocorticographic oscillatory activity predicts resting state functional magnetic resonance imaging connectivity. Society for Neuroscience, Washington DC, November, 2014.
 12. Entz L, Toth E, Fabo D, **Keller CJ**, Bickel S, Eross L, Ulbert I, Mehta AD. Cortico-cortical evoked potentials may reveal pathological and function networks in the brain. Human Brain Mapping, Hamburg, Germany, June, 2014.
 13. Groppe DM, Megevand P, Bickel S, **Keller CJ**, Goldfinger M, Mehta AD. Coherence vs fluctuations in high gamma band activity for defining resting state functional connectivity in the electrocorticogram. Human Brain Mapping, Hamburg, Germany, June, 2014.
 14. **Keller CJ**, Davidesco I, Megevand P, Groppe DM, Lado FA, Mehta AD. A causal role of the fusiform face area in face perception. Human Brain Mapping, Hamburg, Germany, June, 2014.
 15. Entz L, Toth E, **Keller CJ**, Groppe D, Megevand P, Fabo D, Ulbert I, Eross LG, Mehta AD. Evoked effective connectivity of the human neocortex and identification of seizure network properties. Cognitive Neuroscience, Boston, MA, April, 2014.
 16. Megevand P, Goldfinger MS, Groppe DM, **Keller CJ**, Bickel S, Hwang ST, Fallil Z, Harden CL, Mehta AD. Safety of cortico-cortical evoked potentials by low-frequency stimulation of intracranial electrodes. American Epilepsy Society, Washington DC, December, 2013.

17. Groppe, D.M., Bickel, S., **Keller, CJ**, Kingsley, P.B., Mehta, A.D. (2013) Identification of eloquent cortical areas using resting state fMRI: A validation with in vivo direct cortical electrical stimulation in humans. Curing the Epilepsies 2013: Pathways Forward.
18. Groppe D, Entz L, Bickel S, **Keller CJ**, Megevand P, Mehta AD. Analysis of functional and effective brain networks using electrocorticography and corticocortical evoked potentials: correspondence with fMRI and beyond. Society for Neuroscience, San Diego, November, 2013.
19. **Keller CJ**, Groppe DM, Megevand P, Bickel S, Mehta AD. Electrophysiological Analysis of Default Mode Network Demonstrates Functional and Effective Connectivity. Society for Neuroscience, San Diego, November, 2013.
20. Groppe DM, Megevand P, Bickel S, **Keller CJ**, Mehta AD. Delineation of eloquent cortical areas via resting state functional connectivity as measured by functional magnetic resonance imaging and the electrocorticogram. American Epilepsy Society, Washington DC, 2013.
21. Megevand P, Goldfinger M, Groppe DM, **Keller CJ**, Bickel S, Entz L, Mehta AD. Safety of cortico-cortical evoked potentials by low frequency stimulation of intracranial electrodes. American Epilepsy Society, Washington DC, 2013.
22. Toth E, Entz L, **Keller CJ**, Fabo D, Bickel S, Kozak LR, Eross L, Ulbert I, Mehta AD. Cortical electrical stimulation may reveal pathological and functional networks in the human brain. Hungarian Neuroscience Meeting, Budapest, Hungary, January 17-19, 2013.
23. Entz L, Toth E, **Keller CJ**, Bickel S, Fabo D, Kozak LR, Eross L, Ulbert I, Mehta AD. Anatomico-functional parcellation of the brain based on human electrical stimulation data. Hungarian Neuroscience Meeting, Budapest, Hungary, January 17-19, 2013.
24. **Keller CJ**, Entz L, Ahn S, Davidesco I, Groppe D, Bickel S, Toth E, Kingsley PB, Hwang S, Jain S, Ulbert I, Malach R, Lado F, Mehta AD. The electrophysiological signature of the default mode network. Human Brain Mapping, Seattle, Washington, June 13-17, 2013.
25. Golan T, Davidesco I, Groppe DM, Melloni L, Zion-Golumbic E, **Keller CJ**, Schroeder CE, Mehta A, Malach R. An ECoG exploration of the neural correlates of perceptual continuity during eye blinks. Human Brain Mapping, Seattle, Washington, June 13-17, 2013.
26. Entz L, **Keller CJ**, Toth E, Ulbert I, Eross L, Mehta AD. Electrical stimulation and functional MRI based multimodal approach to map functional and pathological brain areas. Society for British Neurological Surgeons, May 22-24, 2013.
27. Groppe D, Bickel S, **Keller CJ**, Jain S, Hwang S, Harden C, Mehta AD. Oscillations characteristic of non-epileptogenic neocortex in a resting state. American Epilepsy Society, San Diego, CA, November 29-December 4, 2012.
28. **Keller CJ**, Entz L, Bickel S, Groppe DM, Toth E, Kingsley P, Harden C, Hwang S, Jain S,

- Lado FA, Ulbert I, Mehta AD. Multimodal investigation of the segregation of functional and pathological networks. American Epilepsy Society, San Diego, CA, November 29-December 4, 2012.
29. Entz E, Toth E, **Keller CJ**, Bickel S, Groppe D, Ulbert I, Eross L, Mehta AD. Single Pulse Electrical Stimulation is a Promising Tool for Delineating the Seizure Focus Using Network Analysis. European Association of Neurological Societies, Bratislava, Slovakia, October 24-27, 2012.
 30. Toth E, Entz L, Fabo D, **Keller CJ**, Bickel S, Kozak LR, Eross L, Ulbert I, Mehta AD. Pathological and functional network connectivity analysis in the human brain using single pulse electrical stimulation. *International Brain Research Organization*, Szeged, Hungary, Jan 19 - 21, 2012
 31. Entz L, Bickel S, **Keller CJ**, Toth E, Eross L, Ulbert I, Mehta AD. Single Pulse Electrical Stimulation (SPES) is a Promising Tool for Localizing Functional and Pathological Networks. *American Association of Neurological Surgeons*, Miami, FL, April 14-18, 2012.
 32. Jain S, Bickel S, Entz L, **Keller CJ**, Groppe D, Hwang S, Lado F, Mehta AD. Electrode localization in epilepsy surgery – developing a more accurate methodology. *American Epilepsy Society*, Baltimore, MD, December 4-8, 2011.
 33. **Keller CJ**, Bickel S, Jain S, Groppe D, Entz L, Kelley C, Hwang S, Lado F, Mehta AD. Using correlated resting BOLD signal fluctuations to delineate seizure networks *American Epilepsy Society*, Baltimore, MD, December 4-8, 2011.
 34. Groppe D, Bickel L, **Keller CJ**, Entz L, Mehta A. Dominant frequencies of human cortical areas as measured by electrocorticogram and direct stimulation of the cortical surface. *Society for Neuroscience*, Washington, DC, November 9-14, 2011.
 35. Entz L, Bickel L, **Keller CJ**, Toth E, Ulbert I, Eross L, Mehta A. Resting state functional MRI and single pulse electrical stimulation (SPES) are possible new methods to map functional brain networks. *14th European Congress of Neurosurgery*, Rome, Italy, October 9-14, 2011. **Won best poster in stereotactic / functional section.**
 36. Entz L, Bickel L, Toth E, **Keller CJ**, Vakili S, Corines J, Stream S, Sanjay J, Ulbert I, Mehta A. Identifying brain networks using single pulse electrical stimulation and resting state functional MRI connectivity analysis. *Congress of Neurological Surgeons*, Washington DC, October 1-6, 2011.
 37. **Keller CJ**, Entz L, Bickel S, Honey CJ, Jain S, Groppe D, Hwang S, Lado F, Mehta AD. Probing the human connectome: Cortico-cortical evoked potentials reveal projectors and integrators within human brain networks. *Neuroinformatics*, Boston, MA, September 4-6, 2011.
 38. Dykstra AD, Chan AM, Zepeda R, **Keller CJ**, Quinn BT, Cash SS. Individualized localization and cortical surface-based registration of semi-chronic intracranial electrodes. *Human Brain*

Mapping, Quebec, CA, June 26-30, 2011.

39. Entz L, Bickel L, **Keller CJ**, Tóth E, Erőss L, Ulbert I, Mehta AD. Noninvasive Connectivity Analysis: A Novel Methodology for Functional Cortical Mapping. *The American Association of Neurological Surgeons Meeting*, Denver, CO, April 9-13, 2011.
40. Entz L, Bickel L, **Keller CJ**, Tóth E, Erőss L, Ulbert I, Mehta AD. Noninvasive Connectivity Analysis: A Novel Methodology for Functional Cortical Mapping. *The 13th Conference of the Hungarian Neuroscience Society*, Budapest, Hungary, January 20-22, 2011.
41. **Keller CJ**, Entz L, Bickel S, Hwang W, Jain S, Mehta AD. Identifying pathological and functional networks with single pulse electrical stimulation in patients with intractable epilepsy. *American Epilepsy Society*, San Antonio, TX, December 4-8, 2010.
42. Bickel S, Entz L, **Keller CJ**, Kelley C, Jain S, Hwang S, Mehta AD. Localization of epileptic and functional networks at rest using independent component and functional connectivity analysis of the BOLD signal. *American Epilepsy Society*, San Antonio, TX, December 4-8, 2010.
43. Bickel S, **Keller CJ**, Entz L, Kelley C, P. Kingsley, Jain S, Hwang S, Mehta AD. Probing language networks with electrical intracranial fMRI and resting state functional connectivity analysis. *Society for Neuroscience*, San Diego, CA, November 15-20, 2010.
44. **Keller CJ**, Bickel S, Entz L, Hwang S, Jain S, Mehta AD. Identifying pathological and functional networks with single pulse electrical stimulation and resting state functional MRI in patients with intractable epilepsy. *American Medical Association Research Symposium*, San Diego, CA, November 5-6, 2010.
45. Bickel S, Entz L, **Keller CJ**, Kelley C, P. Kingsley, Jain S, Hwang S, Mehta AD. Probing language networks with electrical intracranial fMRI and resting state functional connectivity analysis. *Cleveland Clinic Epilepsy Symposium*, Cleveland, OH, October 1-3, 2010.
46. Cash SS, **Keller CJ**, Ulbert I, Truccolo W, Cole AJ, Gale JT, Eskandar E, Thesen T, Carlson C, Devinsky O, Kuzniecky R, Doyle W, Madsen JR, Schomer D, Mehta AD, Brown EN, Hochberg L and Halgren E. Successive Engagement of Different Cortical Circuits During Seizure Onset and Propagation. *American Clinical Neurophysiology Society*, San Diego, CA, February 2-7, 2010.
47. **Keller CJ**, Cash SS, Narayanan S, Wang C, Kuzniecky R, Carlson C, Devinsky O, Thesen T, Doyle W, Sassaroli A, Boas DA, Ulbert I, Halgren E. Intracranial microprobe for evaluating neuro-hemodynamic coupling in unanesthetized human neocortex. *Society for Neuroscience*, Washington D.C., November 15-19, 2008.
48. Gow DW, Segawa J, and **Keller CJ**. Interactive processing in the identification of prosodic and segmental units in speech: Evidence from multimodal imaging and Granger analysis. *International Conference on Cognitive and Neural Systems*, Boston, MA, May 14-17, 2008.

49. Weiner V, Cash SS, Eskandar E, **Keller CJ**, Peterfreund RA, Pierce ET, Salazar AF, Szabo MD, Brown EN, Purdon PL. Intracranial neural recordings in deep structures of the human brain during general anesthesia; implications for improved anesthetic monitoring. *MGH Clinical Research Symposium*, May 28, 2009.
50. Gow DW, Segawa J, and **Keller CJ**. Rate normalization and gamma oscillations in phonetic feature integration. *International Conference on Cognitive and Neural Systems*, Boston, MA, May 27-30, 2009.

Invited Lectures

<i>The electrophysiological signature of the DMN</i>	Weizmann Institute, Rehovot, Israel	2013
<i>The neural origins of resting functional brain networks</i>	Human Brain Mapping, Hamburg, Germany	2014
<i>Testing propagation of brain stimulation with implanted electrode arrays</i>	Berenson-Allen Center for Brain Stimulation, Harvard Medical School, Boston	2014
<i>Investigating the neuronal mechanisms underlying repetitive brain stimulation with implantable microelectrode arrays</i>	The Feinstein Institute for Medical Research, Manhasset, New York	2014
<i>Investigating the neuronal mechanisms underlying repetitive brain stimulation with implantable microelectrode arrays</i>	Massachusetts General Hospital, Harvard Medical School, Boston, MA	2015
<i>The neural origins of the default mode network and resting fMRI</i>	New York Psychiatric Institute, Columbia University Medical Center, New York	2015
<i>Investigating the neuronal mechanisms underlying repetitive brain stimulation with implantable microelectrode arrays</i>	Stanford University, Palo Alto, CA	2015
<i>Repetitive brain stimulation induces long-term plasticity across patient populations and spatial scales</i>	Brain Stimulation Conference, Human Brain Mapping, Geneva, Switzerland	2016
<i>Modifying neural circuits with brain stimulation</i>	University of Milan, Milan, Italy	2016
<i>Long-term plasticity underlies antidepressant effect of</i>	Shenzhen University,	2016

<i>repetitive transcranial magnetic stimulation</i>	Shenzhen, China	2017
<i>Simultaneous TMS-EEG as a causal tool to probe functional brain networks</i>	Winter Brain Conference, Big Sky, Montana	2017
<i>Induction and quantification of brain plasticity across populations and scales</i>	Society for Biological Psychiatry, San Diego, CA	2017
<i>Towards personalized rTMS treatment for MDD</i>	Human Brain Mapping, Vancouver, BC	2017
<i>Naturalistic clinical monitoring of rTMS-induced plasticity with TMS-EEG</i>	TMS-EEG Workshop, Helsinki, Finland	2018
<i>Naturalistic clinical monitoring of rTMS-induced plasticity with TMS-EEG</i>	Winter Brain Conference, Vancouver, BC	2018
<i>Personalized Medicine for Subjects with Treatment-Resistant Major Depressive Disorder: Novel Strategies to Optimize Treatment with Antidepressant Medications, rTMS, Ketamine, and ECT</i>	Anxiety and Depression Association of America, Washington, DC	2018
<i>Towards Personalized Neuromodulation</i>	McLean Hospital, Harvard Medical School, Boston, MA	2018
<i>Large-scale, naturalistic rTMS plasticity monitoring</i>	University of Texas Southwestern, Dallas, TX	2018
<i>Towards Personalized Brain Stimulation for Neuropsychiatric Disorders</i>	UCSD, Markou Seminar, San Diego, CA	2018
	Shenzhen University, Shenzhen, China	2019
	Conte Center Series Symposium, Columbia University, New York, NY	2019
	Innovations in Psychiatry Symposium, Mt. Sinai School of Medicine, New York, NY	

Nature Communications
 Journal of Neuroscience
 Neuropsychopharmacology
 Human Brain Mapping
 Neuroreport
 Neuroscientist

Mentoring

Victor Du, MD, Neurosurgical Resident, 2015-2016. *Spike timing dependent plasticity in human cortical networks.*

Danny Huang, Medical Student, 2015-2016. *Monitoring of intracortical plasticity across multiple biological systems.*

Maria Fini, Graduate Student, 2014-2015. *Induction of cortical plasticity following stimulation of human brain networks.*

Samuel Anh, MD, Neurology Resident, Summer 2013. *Electrophysiological origins of the default mode network.*

Emily Batinelli, Medical Student, Summer 2012. *Electrophysiological origins of the default mode network.*

Tasur Seen, Medical Student, 2014. *Selective manipulation of human cortical circuits.*

Collaborations

Electrical modulation of the human fusiform gyrus. *Ido Davidesco and Rafael Malach*, Neuroscience, Weizmann Institute, Israel.

Electrophysiological origins of resting fMRI. *Michael Milham and Clare Kelly*, NYU Psychology.

Induction and quantification of plasticity in human cortical networks. *Ashesh Mehta*, Feinstein Institute for Medical Research.

Relationship of single unit responses to high gamma and multiunit activity in the mouse striatum. *Chris Chen and Kamran Khodakhah*, Einstein Neuroscience.

Electrical stimulation in humans to examine and modulate complex brain networks. *Laszlo Entz and Istvan Ulbert*, Neurosurgery, Hungary Institute, Hungary.

Electrophysiology of anticorrelated resting fMRI. *Michael Fox*, Harvard Neurology.

Media

2018 JNeuro release: <http://neurosciencenews.com/personalized-brain-stimulation-9096/>

2015 Cover article for Albert Einstein College of Medicine MD/PhD graduation

Teaching Experience

Teaching Assistant - Systems Neuroscience Spring 2013

Relevant Skills

Recordings: EEG, ECoG, functional MRI, laminar and tetrode microelectrode recordings, TMS-EEG, electrical and optogenetic stimulation, brain-computer interface, near infrared spectroscopy, laser Doppler flowmetry,

Analysis/design: MATLAB, Labview, Presentation, Illustrator, Photoshop

Professional Training

- 2018 NIH Brain Camp, Cold Spring Harbor Laboratory, NY
- 2018 Career Development Institute, Pittsburgh, PA
- 2017 TMS-EEG Workshop, Helsinki, Finland
- 2016 Combining Brain Stimulation and Neuroimaging Short Course, Geneva, Switzerland
- 2014 NINDS Combining Clinical and Research Careers in Neuroscience, Washington, DC
- 2014 Human Brain Mapping Short Course, Brain Stimulation, Hamburg, Germany
- 2013 Society for Neuroscience Short Course, Advances in ECoG, New Orleans, LA
- 2013 Neural Systems and Behavior, Marine Biology Laboratory, Woods Hole, MA

Other Experience and Professional Memberships

- 2018- Member, Alpha Omega Alpha Medical Honors Society
- 2016- Member, Clinical TMS Society
- 2016- Member, Society of Physician Entrepreneurs
- 2015- Member, Human Brain Mapping
- 2015- Member, International Neuromodulation Society
- 2015- Member, Society of Biological Psychiatry
- 2013- Alumnus, Woods Hole MBL Neural Systems and Behavior Course
- 2009- Member, Society for Neuroscience
- 2009- Member, American Epilepsy Society
- 2009- Member, American Medical Association

Personal Accomplishments

- 2010-2012 Albert Einstein Squash Champion
- 2007 Captain, Tufts Tennis Team, #1 Singles and Doubles
- 2005-2007 ITA Scholar Athlete Award
- 2002 New England High School Tennis Champion